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(12) UK Patent Application (19) GB (11) 2 293 894 (13) A

(43) Date of A Publication 10.04.1996

(21) Application No 9518238.2

(22) Date of Filing 07.09.1995

(30) Priority Data
(31) 316747 (32) 03.10.1994 (33) US

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(51) INT CL^6
F02D 41/18

(52) UK CL (Edition O)
G3N NGE1B N288A
U1S S1990

(56) Documents Cited
US 5357932 A US 5279272 A US 5078107 A

(58) Field of Search
UK CL (Edition N) G3N NGE1 NGE1A NGE1B
INT CL^6 F01L 1/34 1/344, F02D 13/02 41/18 41/34
ONLINE : WPI

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(54) Variable camshaft timing system

(57) An electronic engine controller operates to control the phase angle of a variable position camshaft. The engine controller 10 receives signals indicative of engine coolant temperature 63, aircharge temperature 55, throttle position 53, engine speed 19 and camshaft position 18, and generates a camshaft position signal to a variable camshaft control actuator 40 to alter the phase angle of the camshaft with respect to the engine crankshaft.

The engine controller 10 contains two tables which contain cam phase angles. The first table contains a plurality of values indexed by engine speed and engine aircharge and the second table contains a plurality of values indexed by engine speed and throttle position. The engine controller 10 generates the camshaft position signal in one of three manners depending on the mode of engine operation. In a first mode of engine operation the camshaft position signal is generated as a function of engine coolant temperature and aircharge temperature. In a second mode of engine operation, the camshaft position signal is generated as a function of the values contained in the aforesaid first and second tables, and in a third mode of engine operation the camshaft position signal is generated as a function of a predetermined default value.

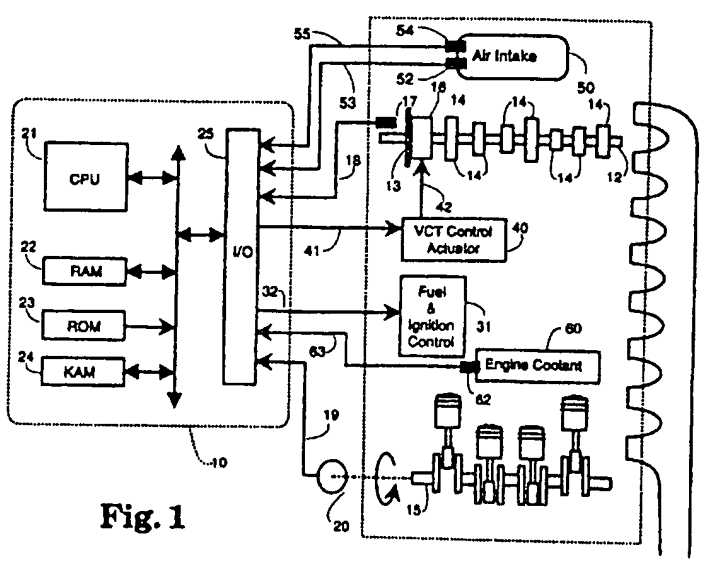

Fig. 1

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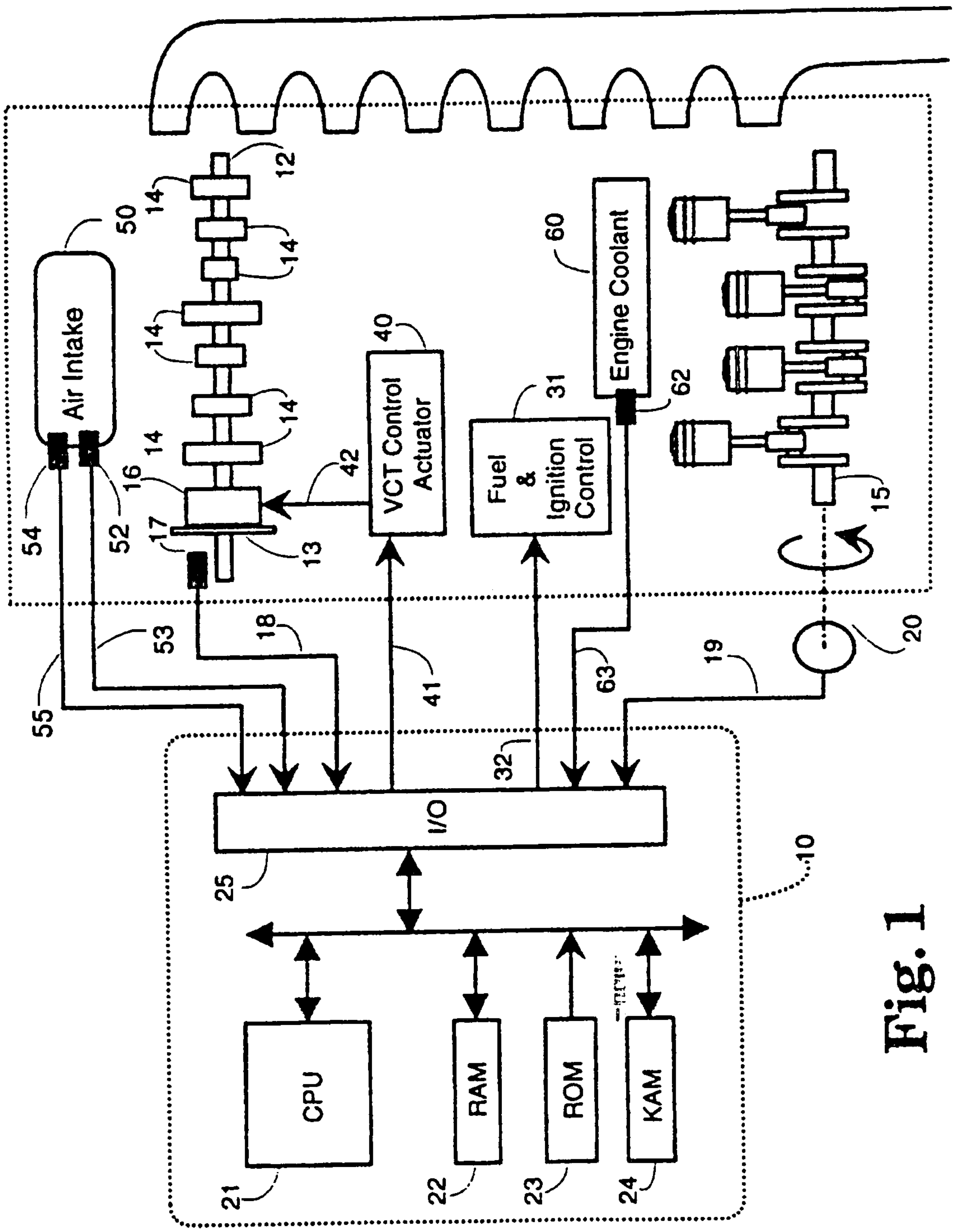
Air Intake
VCT Control Actuator
Fuel & Ignition Control
Engine Coolant
I/O
CPU
RAM
ROM
KAM
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63

Fig. 1

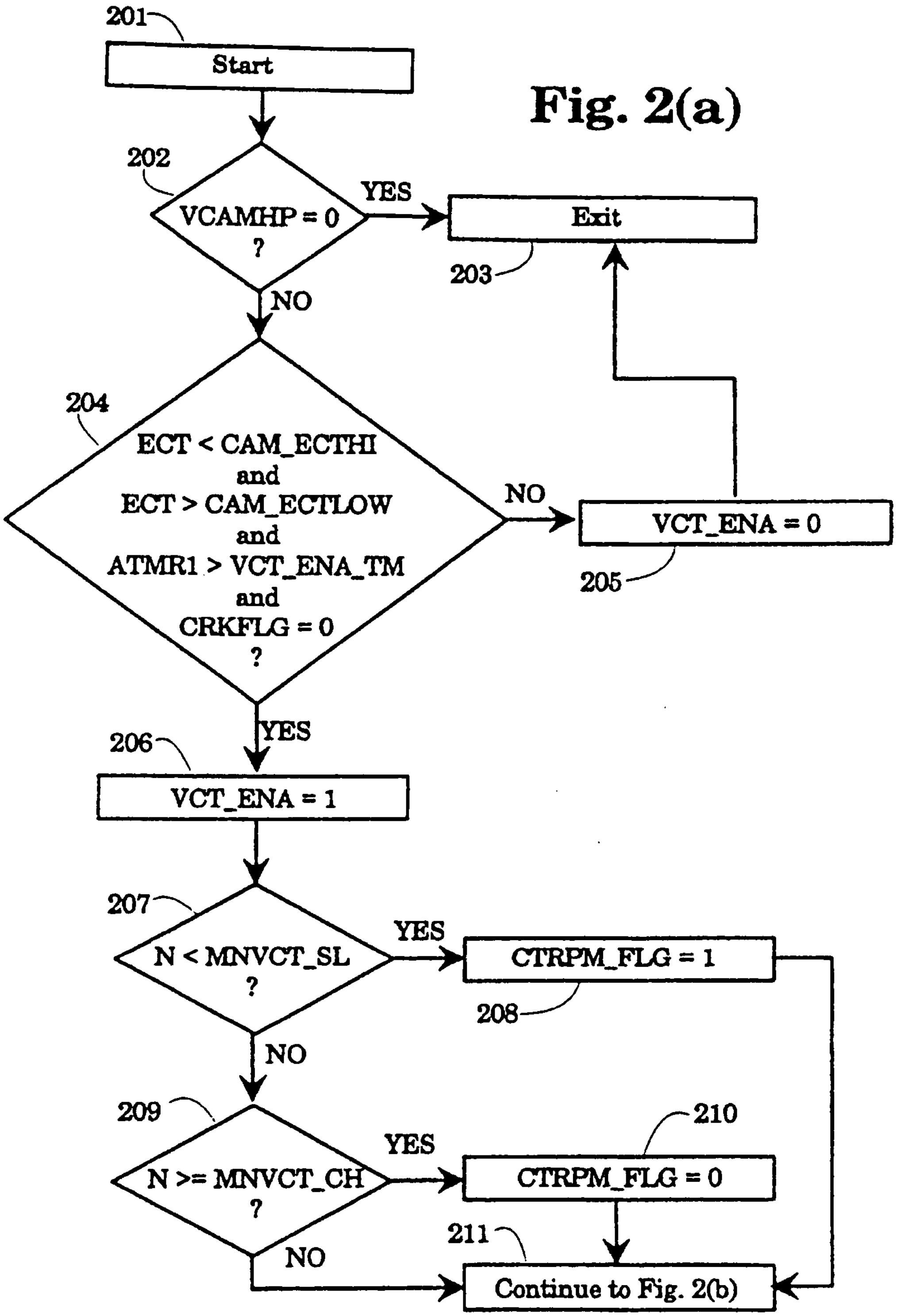
201
Start
202
VCAMHP = 0 ?
YES
Exit
203
NO
204
ECT < CAM_ECTHI and ECT > CAM_ECTLOW and ATMR1 > VCT_ENA_TM and CRKFLG = 0 ?
NO
VCT_ENA = 0
205
YES
206
VCT_ENA = 1
207
N < MNVCT_SL ?
YES
CTRPM_FLG = 1
208
NO
209
N >= MNVCT_CH ?
YES
210
CTRPM_FLG = 0
211
NO
Continue to Fig. 2(b)

Fig. 2(a)

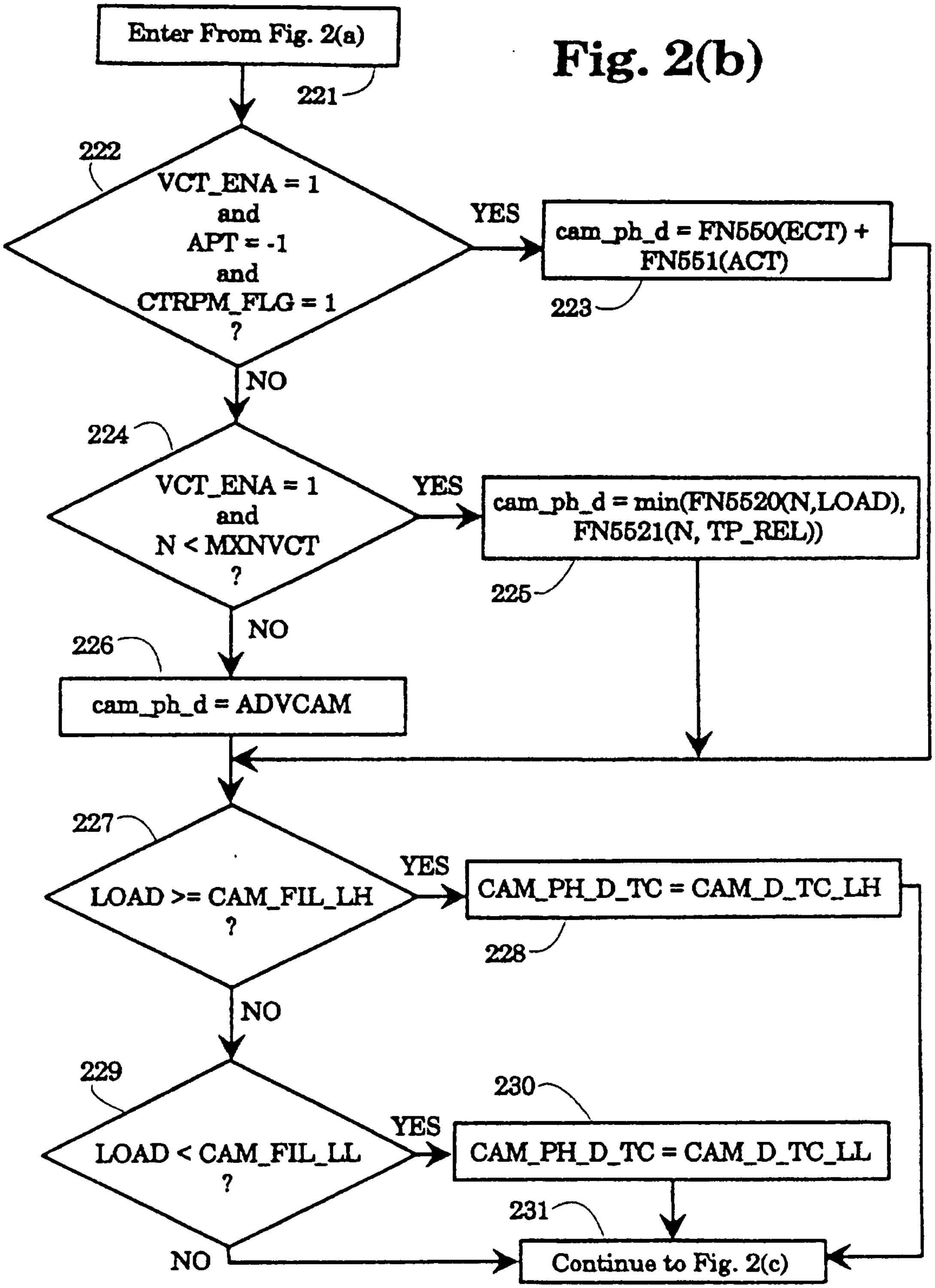
Enter From Fig. 2(a)
221
222
VCT_ENA = 1
and
APT = -1
and
CTRPM_FLG = 1
?
YES
cam_ph_d = FN550(ECT) +
FN551(ACT)
223
NO
224
VCT_ENA = 1
and
N < MXNVCT
?
YES
cam_ph_d = min(FN5520(N,LOAD),
FN5521(N, TP_REL))
225
NO
226
cam_ph_d = ADVCAM
227
LOAD >= CAM_FIL_LH
?
YES
CAM_PH_D_TC = CAM_D_TC_LH
228
NO
229
LOAD < CAM_FIL_LL
?
YES
230
CAM_PH_D_TC = CAM_D_TC_LL
231
NO
Continue to Fig. 2(c)

Fig. 2(b)

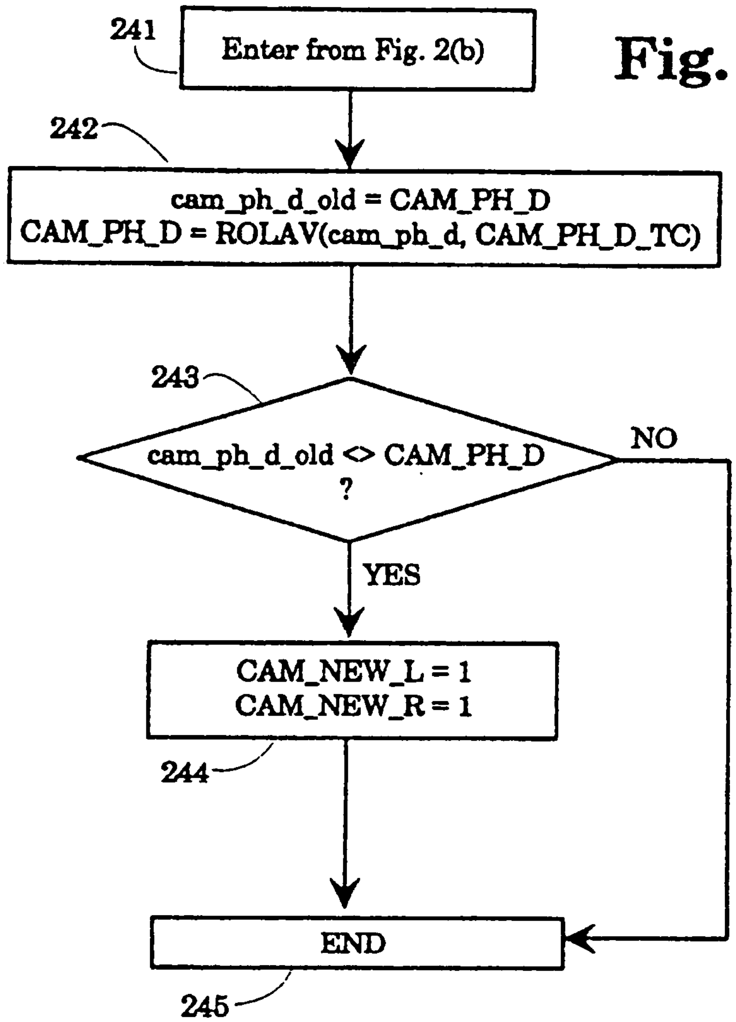
241
Enter from Fig. 2(b)
242
cam_ph_d_old = CAM_PH_D
CAM_PH_D = ROLAV(cam_ph_d, CAM_PH_D_TC)
243
cam_ph_d_old <> CAM_PH_D
?
NO
YES
CAM_NEW_L = 1
CAM_NEW_R = 1
244
END
245

Fig. 2(c)

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VARIABLE CAMSHAFT TIMING SYSTEM

Field of the invention

This invention relates to the field of electronic engine control and more particularly to the field of controlling the position of a variable position camshaft.

Background of the invention

Variable cam timing systems operate to vary the timing between the camshaft and the crankshaft to optimise engine performance over the entire range of engine operation. Systems such as that described in U.S. Patent, 5,117,784 to Schechter et al., vary the timing between the camshaft and crankshaft to achieve improved idle stability, expanded torque curve and the RPM (revolutions per minute) range of the engine, full control of emission gases and elimination of certain emissions, and elimination of external exhaust gas recirculation components and circuitry.

It is known that optimal cam timing for fuel economy and emissions may be achieved by determining the timing as a function of engine speed and aircharge entering the engine in lbs/cylinder filling. Optimal cam timing for performance may be achieved by determining the cam timing as a function of engine speed and throttle position. Either of the aforesaid control methods can generate cam timing to achieve satisfactory fuel economy, emissions and performance for a particular altitude, usually sea level. However, as the altitude at which a vehicle is operated increases a control method calibrated for sea level operation provides less than optimal results because the aircharge entering the engine at a given throttle position decreases. Exclusive use of throttle position to determine cam timing causes too much retard and charge dilution at low aircharge levels. Exclusive use of aircharge to determine cam timing causes

too much retard at high throttle angles and peak power is not achieved.

Accordingly, there is a need for a variable cam timing system which provides optimal fuel economy, emissions and performance at a variety of altitudes.

Object of the invention

The present invention seeks to control the timing of a variable camshaft to achieve optimum fuel economy, emissions and performance under a variety of engine operating conditions.

Summary of the invention

In accordance with the present invention, there is provided a method of setting the cam phase angle of a camshaft in a vehicle engine that includes a variable cam timing system for altering the angular position of the camshaft to advance and retard camshaft timing from a base camshaft position, the comprising the steps of:

generating an engine speed value indicative of the rotational speed of the engine;

generating an aircharge value indicative of the aircharge entering the engine;

generating a throttle position value indicative of the throttle position of the engine;

retrieving a first camshaft phase angle as a function of the engine speed value and the aircharge value;

retrieving a second camshaft phase angle as a function of the engine speed value and the throttle position value;

comparing the first camshaft phase angle to the second camshaft phase angle; and

setting the cam phase angle as a function of the camshaft phase angle which corresponds to the least amount of camshaft timing retard.

In accordance with a second aspect of the invention, there is provided a variable camshaft timing system comprising:

means for generating an rpm signal indicative of the rotational speed of the engine;

means for generating an aircharge signal indicative of engine aircharge;

means responsive to the rpm signal and to the aircharge signal for generating a first cam timing value indicative of a first camshaft phase angle;

means for generating a throttle position signal indicative of engine throttle position;

means responsive to the rpm signal and to the throttle position signal for generating a second cam timing value indicative of a second camshaft phase angle, and

means for comparing the first camshaft phase angle to the second camshaft phase angle and for generating a phase angle for the camshaft which corresponds to the lesser of the first camshaft phase angle and the second camshaft phase angle.

In accordance with a further aspect of the invention, there is provided A variable camshaft timing system comprising:

means for generating an rpm signal indicative of the rotational speed of the engine,

means for generating an aircharge signal indicative of engine aircharge,

means responsive to the rpm signal and to the aircharge signal for retrieving a first cam timing value indicative of a first camshaft phase angle;

means for generating a throttle position signal indicative of engine throttle position,

means responsive to the rpm signal and to the throttle position signal for retrieving an interpolator value;

means responsive to the rpm signal for retrieving a second cam timing value indicative of a second camshaft phase angle; and

means responsive to the interpolator value for generating the cam phase angle by interpolating the cam phase angle from the first cam timing value and the second cam timing value.

Brief description of the drawings

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which :-

Fig. 1 shows a portion of an internal combustion engine and electronic engine controller; and

Figs. 2(a), 2(b) and 2(c) are flowcharts showing the operation of a preferred embodiment of the invention.

Detailed description of the preferred embodiment

In Fig. 1 an internal combustion engine comprises a variable position camshaft 12 capable of altering the positional relationship of cam lobes 14 to crankshaft 15. Such a variable position camshaft is described in U.S. Patent No. 5,117,784 to Schechter et al. Fig. 1 shows for explanation purposes a single variable position camshaft. It is understood that engines using either an in-line cylinder configuration or a V-type cylinder configuration may have multiple camshafts of the type shown in Fig. 1. A pulsewheel 13 positioned on a drive gear 16 of the camshaft 12 comprises a plurality of teeth (not shown) positioned in fixed relationship to the cams 14 on the camshaft 12. A VRS sensor 17, of known type, detects the angular rotation of the teeth on the pulsewheel 13 as the camshaft rotates and generates a representative Variable Cam Timing/Cylinder Identification (VCT/CID) signal 18. VCT control actuator 40 receives camshaft position signal 41, which is indicative of a cam phase angle in degrees from a default phase angle, from an electronic engine control (EEC) module 10 and generates a camshaft control signal 42 used to control the

angular position of cams 14 relative to crankshaft 15. Camshaft position signal 41 preferably takes the form of a duty cycle signal to reduce sensitivity to voltage fluctuations. A Crankshaft Position Sensor (CPS) 20 generates a CPS signal 19 indicative of the rotational speed of the crankshaft 15. A throttle position sensor 52 of known type positioned in air intake 50 generates a throttle position signal 53 which is indicative of the position of the throttle (not shown), and aircharge temperature sensor 54 generates an aircharge temperature signal 55 which is indicative of the temperature of the aircharge entering air intake 50. An engine coolant temperature sensor 62 of known type generates an engine coolant temperature signal 63 which is indicative of the temperature of engine coolant circulating through the engine.

The electronic engine control (EEC) module 10 comprises a central processing unit 21, a read-only memory (ROM) 23 for storing control programs, a random-access memory (RAM) 22 for temporary data storage, a keep-alive-memory (KAM) 24 for storing learned values and a conventional data bus. The EEC 10 receives the VCT/CID signal 18, the CPS signal 19, engine coolant temperature signal 63, throttle position signal 53, and aircharge temperature signal 55 and generates control signals 32 to control the amount of fuel injected by injectors within the engine, and control the spark ignition of an air/fuel mixture within the combustion chambers of the engine. EEC 10 generates digital values which correspond to the information received from signals 18, 19, 63, 53 and 55. A VCT/CID value is generated from VCT/CID signal 18, an RPM value is generated from CPS signal 19, an ECT value is generated from engine coolant temperature signal 63, a throttle position value is generated from throttle position signal 53 and an ACT value is generated from aircharge temperature signal 55. The EEC 10 also controls the relationship of the two input signals 18, and 19 by generating a cam phase angle which is transmitted via

camshaft position signal 41 from the EEC, to the VCT control actuator 40.

The described preferred embodiment advantageously determines a cam phase angle and generates camshaft position signal 41 as a function of the cam phase angle in a manner which optimises fuel economy, emissions and performance at all altitudes, by executing the camshaft timing routine shown in figs. 2(a), 2(b) and 2(c). The steps in figs. 2(a), 2(b) and 2(c) are preferably executed by EEC 10 in a background loop. The camshaft timing routine is initiated in fig. 2(a) at 201. At 202 a calibration constant VCAMHP, which indicates whether VCT hardware is present in the engine is checked. VCAMHP is preferably a binary value with a value of one indicating that VCT hardware is present. If VCAMHP is found to be equal to zero, then the routine determines that VCT hardware is not present in the engine and the routine is exited at 203. Otherwise, at 204, a test is performed to determine if the engine is within an operating range in which variable camshaft timing may be enabled.

The described preferred embodiment utilises variable camshaft timing once the engine has been operating a predetermined minimum amount of time from engine crank and is operating within a predetermined engine coolant temperature range. Variable ECT which is indicative of the temperature of engine coolant indicated by engine coolant temperature signal 63 is compared against two constants, namely CAM_ECTHI and CAM_ECTLOW, which respectively represent maximum and minimum engine coolant operating temperatures for operation of variable camshaft timing. Also at 204, variable ATMR1 which is representative of the time elapsed since exiting crank mode is checked against constant VCT_ENA_TM which is indicative of a minimum amount of time elapsed from crank mode before variable camshaft timing may begin. Finally, at 204, flag CRKFLG is checked to determine if the engine is in crank mode. CRKFLG has a value of one if the engine is in crank mode and a value of zero otherwise.

If the engine coolant temperature is within the predetermined range, the engine is not in crank mode and the predetermined amount of time has elapsed since crank mode, then at 206, a VCT enabling flag, VCT_ENA is set to a value of one and the routine is continued. Otherwise, at 205 VCT_ENA is set to zero and the routine is exited.

If VCT_ENA is set to zero then variable cam timing is disabled and the camshaft is positioned at a predetermined default angle with respect to the crankshaft. In the preferred embodiment, the default angle is a value which corresponds to the most advanced cam timing allowed by the characteristics of the engine.

At 207 and 209 tests are performed to determine if a closed throttle VCT mode should be enabled. In the preferred embodiment, a closed throttle VCT mode is used primarily at selected RPMs such as idle to minimise emissions while maintaining driveability. At 207, engine speed variable N which is indicative of the rotational speed of the engine in revolutions per minute (RPM) is compared to constant MNVCT_SL which is indicative of a maximum engine speed, in RPMS, below which closed throttle VCT mode may be enabled. If N is less than MNVCT_SL then at 208, a flag CTRPM_FLG is set to a value of one to indicate that the engine speed is low enough to enable closed throttle VCT mode. Otherwise at 209, N is compared to constant MNVCT_CH which is indicative of a minimum engine speed at which closed throttle VCT mode may be enabled. If N is greater than or equal to MNVT_CH then at 210 flag CTRPM_FLG is set to a value of zero to indicate engine speed is too high to operate in closed throttle VCT mode. Otherwise, CTRPM_FLG is not altered and as seen at 211, the routine proceeds to the steps shown in fig. 2(b).

At steps 223, 225 and 226, a desired cam phase angle is determined in one of three ways depending upon the results of tests performed at steps 222 and 224, which determine the operational mode of the engine. In the preferred embodiment, the routine, through steps 222 and 224 determines the engine

to be operating in one of three modes, namely closed throttle VCT mode, normal mode, and high engine speed mode. At 222, VCT_ENA and CTRPM_FLG are checked to ensure that variable cam timing and closed throttle VCT mode are enabled. Also at 222, a throttle mode value APT is checked to determine the position of the throttle. APT has a value of minus one (- 1) at closed throttle, a value of zero at part throttle and a value of one at wide open throttle. If at 222, variable cam timing and closed throttle VCT mode are found to be enabled and the engine is operating in closed throttle VCT mode, then at 223 desired cam phase angle value cam_ph_d is determined as a function of engine coolant temperature and aircharge temperature. As seen at 223, cam_ph_d is determined by adding a first value FN550(ECT) to a second value FN551(ACT). In the preferred embodiment, first value FN550(ECT) is obtained from a one-dimensional table of stored, empirically determined values which are indexed by engine coolant temperature value ECT. Second value FN551(ACT) is similarly preferably retrieved from a one-dimensional table of stored, empirically determined values which are indexed by aircharge temperature. In the preferred embodiment both tables are stored in ROM 23. As will be appreciated by those skilled in the art, generation of a desired cam phase angle as a function of engine coolant temperature and aircharge temperature in the manner shown in step 223, when the engine is operating in closed throttle VCT mode, advantageously generates a cam timing angle which provides optimum emissions and driveability at all engine coolant temperatures.

If any of the conditions at 222 is found not to be true, then at 224, the value of VCT_ENA is checked and the engine speed is checked by comparing the engine speed variable N to constant MXNVCT which is indicative of a maximum acceptable engine speed, in RPMs, for variable cam timing to be utilised. If variable cam timing is enabled (VCT_ENA = 1) and if the engine speed N is less than MXNVCT then the engine is determined to be operating in normal mode and at

225, desired cam phase angle value cam_ph_d is determined as the minimum of a value provided by an economy function which generates a desired cam phase angle as a function of engine speed and engine aircharge and a performance function which generates a desired cam phase angle as a function of engine speed and relative throttle position. As seen at 225, cam_ph_d is determined by taking the minimum of a first value, FN5520(N,LOAD) and a second value FN5521(N,TP_REL). In the preferred embodiment, first value FN5520(N,LOAD) is obtained from a two-dimensional table of stored, empirically determined values which are indexed by engine speed N and engine aircharge LOAD, where LOAD is normalised cylinder aircharge. The cam phase angles contained in the table are indicative of cam timing which provide minimum fuel consumption while achieving government regulated emissions and acceptable combustion stability. As will be appreciated by those skilled in the art, such cam phase angles advantageously provide limited cam retard to provide the aforementioned advantages. The two-dimensional table FN5520 will hereafter be referred to as the economy table. Second value FN5521(N, TP_REL) is similarly preferably retrieved from a two-dimensional performance table of stored, empirically determined values which are indexed by engine speed N and relative throttle position TP_REL, where TP_REL is throttle position measured from a throttle body hard set of the engine. The cam phase angles contained in the performance table are indicative of cam timing which provides good driveability. The combined use of economy table FN5520 and performance table FN5521, under the conditions tested at steps 222 and 224, advantageously provide limited cam retard at high throttle positions to maintain good driveability and power and ensure a smooth transition to the cam timing necessary for maximum power, particularly when the vehicle is driven at high altitudes where aircharge is reduced. In the preferred embodiment, the economy table and the performance table are both stored in ROM 23.

In an alternative embodiment, desired cam phase angle cam_ph_d is generated at step 225 as a function of a value retrieved from economy table FN5520, an interpolator value retrieved from a interpolator table, and a wide-open throttle value retrieved from a wide-open throttle table. The interpolator table contains a plurality of interpolator values, indexed by engine speed N and throttle position TP_REL. Preferably the interpolator values have a value between zero and one, with a value of one indicating a high throttle position and a value of zero indicating a low throttle position. The wide-open throttle table contains a plurality of wide-open throttle values each of which is indicative of a desired cam phase angle at a particular engine speed, when the engine is being operated in the high engine speed mode. In such an embodiment, the desired cam phase angle cam_ph_d is generated by the following relationship:

$$cam\_ph\_d = FN5520(N,LOAD)*(1-VCTINTERP) + VCTWOT*VCTINTERP$$

where, FN5520(N, LOAD) is a cam phase angle retrieved from economy table FN5520, VCTINTERP is an interpolator value retrieved from the interpolator table, and VCTWOT is a wide-open throttle value retrieved from the wide-open throttle table.

In the above relationship, interpolator value VCTINTERP will equal zero at low throttle positions, and consequently, cam_ph_d will equal the value retrieved from economy table FN5520. At high throttle positions, interpolator value VCTINTERP will equal one, and consequently, cam_ph_d will equal the wide-open throttle value VCTWOT. For partial throttle positions, the interpolator value will have a value between zero and one and will effect an interpolation of the desired cam phase angle from the values stored in the economy table and the wide-open throttle table. A cam phase angle generated in the above manner, advantageously provides optimum cam timing for situations in which the optimum cam

timing for power is not always more advanced than the optimum cam timing for emissions.

If the conditions at 224 are not satisfied, then the engine is determined to be operating in high engine speed mode and at 226, desired cam phase angle cam_ph_d is set equal to a predetermined cam phase angle ADVCAM which preferably corresponds to the most advanced cam timing allowed by the characteristics of the engine.

Once a desired cam phase angle is determined at steps 222 through 226, the desired cam phase angle is filtered at steps 227 through 230 in fig. 2(b) and steps 242 through 244 in fig. 2(c). Such a function advantageously improves vehicle driveability by minimising the effects of excessively high frequency changes in input parameters such as engine speed, engine coolant temperature, throttle position, and aircharge temperature on the cam phase angle.

At steps 227 through 230 a filtering time constant CAM_PH_D_TC is determined as a function of the engine aircharge as represented by the variable LOAD. The preferred embodiment advantageously selects a filter time constant depending upon engine aircharge. If at 227, LOAD is greater than or equal to a constant CAM_FIL_LH then at 228, filter time constant CAM_PH_D_TC is set equal to a first time constant CAM_D_TC_LH. Otherwise, at 229, LOAD is compared to a constant CAM_FIL_LL, and at 230, CAM_PH_D_TC is set equal to a second time constant CAM_D_TC_LL if LOAD is less than CAM_FIL_LL. Otherwise if aircharge is within the range established by CAM_FIL_LL and CAM_FIL_LH then filter time constant CAM_PH_D_TC is maintained at its existing value. Constants CAM_FIL_LH and CAM_FIL_LL establish an upper and lower limit, respectively, for a range which advantageously avoids rapid fluctuation of time constants.

In fig. 2(c), at 242, an actual cam phase angle CAM_PH_D is generated by filtering desired cam phase angle cam cam_ph_d as a function of filter time constant CAM_PH_D_TC. The filtering is advantageously performed by taking the rolling average of desired cam phase angle

cam_ph_d as a function of filter time constant CAM_PH_D_TC. As can be seen at 242, the value of actual cam phase angle CAM_PH_D is stored by setting variable cam_ph_d_old equal to CAM_PH_D.

At 243, the former actual cam phase angle cam_ph_d_old is compared to the present actual cam phase angle CAM_PH_D to determine if camshaft position signal 41 requires alteration in order to command VCT control actuator 40 to alter the angular position of camshaft 12 in accordance with actual cam phase angle CAM_PH_D. If at 243, cam_ph_d_old is not equal to CAM_PH_D, then at 244, flags CAM_NEW_L and CAM_NEW_R are set to a value of one to indicate that a new unused cam phase angle is available. If CAM_NEW_L and CAM_NEW_R are set to a value of one then camshaft position signal 41 will be altered in a separate VCT command routine to command VCT control actuator 40 to change the position of camshaft 12. VCT command routine is initiated periodically by checking the value of CAM_NEW_L and CAM_NEW_R and continuing to alter the camshaft position signal 41 if either of the flags has a value of one. Once camshaft position signal 41 is altered, CAM_NEW_L and CAM_NEW_R are set to a value of zero to indicate that the position of camshaft 12 corresponds to the value of actual cam phase angle CAM_PH_D. Values CAM_NEW_R and CAM_NEW_L are required for an engine which utilises two camshafts. In an engine which having a single camshaft, one of the aforesaid flags is not required.

If at 243, cam_ph_d_old is found to equal CAM_PH_D, then the value of CAM_NEW_L and CAM_NEW_R is not altered and the routine is exited at 243. In such a situation, camshaft position signal 41 will not be altered by the VCT command routine.

It is to be understood that the specific mechanisms and techniques which have been described are merely illustrative of one application of the principles of the invention. Modifications may be made to the method and apparatus

described without departing from the scope of the invention as set out in the appended claims.

CLAIMS

1. A method of setting the cam phase angle of a camshaft in a vehicle engine that includes a variable cam timing system for altering the angular position of the camshaft to advance and retard camshaft timing from a base camshaft position, the comprising the steps of:

generating an engine speed value indicative of the rotational speed of the engine;

generating an aircharge value indicative of the aircharge entering the engine;

generating a throttle position value indicative of the throttle position of the engine;

retrieving a first camshaft phase angle as a function of the engine speed value and the aircharge value;

retrieving a second camshaft phase angle as a function of the engine speed value and the throttle position value;

comparing the first camshaft phase angle to the second camshaft phase angle; and

setting the cam phase angle as a function of the camshaft phase angle which corresponds to the least amount of camshaft timing retard.

2. A method as claimed in claim 1, wherein the vehicle is operated in a plurality of operating modes including a closed throttle VCT mode, a normal mode and a high engine speed mode and wherein the steps of the method are executed in the normal mode.

3. A method as claimed in claim 2, further comprising the step of generating an engine temperature signal which is indicative of the temperature of the engine, and operating the vehicle in the default mode when the engine temperature signal indicates an engine temperature below a predetermined minimum temperature.

4. A method as claimed in claim 3, wherein the engine temperature signal is indicative of the temperature of an engine coolant within the engine.

5. A method as claimed in claim 4, wherein the step of determining the cam phase angle comprises the steps of determining a desired phase angle as a function of the camshaft phase angle which corresponds to the least amount of camshaft timing retard, generating a rolling average of the desired phase angle and a filter value, and determining the cam phase angle as a function of the rolling average.

6. A method as claimed in claim 5, wherein the step of generating a rolling average of the desired phase angle and a filter value comprises the step of determining the filter value as a function of engine aircharge.

7. A method as claimed in claim 6, wherein the step of determining the filter value as a function of engine aircharge comprises the steps of comparing an engine aircharge value which is indicative of engine aircharge to a minimum aircharge value and to a maximum aircharge value and determining the filter value as a function of a first predetermined filter value if the engine aircharge value is greater than or equal to the maximum aircharge value and determining the filter value as a function of a second predetermined filter value if the engine aircharge value is less than the minimum aircharge value.

8. A method as claimed in claim 2 or any claim appended thereto, further comprising the steps of:

generating an engine coolant temperature value indicative of the temperature of engine coolant within the engine;

generating an aircharge temperature value indicative of the temperature of an aircharge entering the engine; and

if the engine is operating in the closed throttle VCT mode,

retrieving a first closed throttle camshaft phase angle as a function of the engine coolant temperature value;

retrieving a second closed throttle camshaft phase angle as a function of the aircharge temperature value; and

setting the cam phase angle as the sum of the first closed throttle camshaft phase angle and the second closed throttle camshaft phase angle.

9. A method as claimed in claim 8, further comprising the step of setting the cam phase angle as a function of a predefined cam phase angle if the engine is operating in the high engine speed mode.

10. A variable camshaft timing system comprising:

means for generating an rpm signal indicative of the rotational speed of the engine;

means for generating an aircharge signal indicative of engine aircharge;

means responsive to the rpm signal and to the aircharge signal for generating a first cam timing value indicative of a first camshaft phase angle;

means for generating a throttle position signal indicative of engine throttle position;

means responsive to the rpm signal and to the throttle position signal for generating a second cam timing value indicative of a second camshaft phase angle, and

means for comparing the first camshaft phase angle to the second camshaft phase angle and for generating a phase angle for the camshaft which corresponds to the lesser of the first camshaft phase angle and the second camshaft phase angle.

11. A variable camshaft timing system as claimed in claim 10, wherein the lesser of the first camshaft phase

angle and the second camshaft phase angle corresponds to the least amount of camshaft timing retard.

12. A variable camshaft timing system comprising:

means for generating an rpm signal indicative of the rotational speed of the engine,

means for generating an aircharge signal indicative of engine aircharge,

means responsive to the rpm signal and to the aircharge signal for retrieving a first cam timing value indicative of a first camshaft phase angle;

means for generating a throttle position signal indicative of engine throttle position,

means responsive to the rpm signal and to the throttle position signal for retrieving an interpolator value;

means responsive to the rpm signal for retrieving a second cam timing value indicative of a second camshaft phase angle; and

means responsive to the interpolator value for generating the cam phase angle by interpolating the cam phase angle from the first cam timing value and the second cam timing value.

13. A variable camshaft timing system as claimed in claim 12, wherein the first cam timing value is retrieved from a first table which comprises a plurality of cam timing values which are indexed by engine speed and engine aircharge.

14. A variable camshaft timing system as claimed in claim 13, wherein the second cam timing value is retrieved from a second table which comprises a plurality of cam timing values which are indexed by engine speed.

15. A variable camshaft timing system adapted to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9518238.2

Relevant Technical Fields

(i) UK Cl (Ed.N) G3N (NGE1, NGE1A, NGE1B)

(ii) Int Cl (Ed.6) F01L (1/34, 1/344) F02D (13/02, 41/18, 41/34)

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) WPI

Search Examiner
MR D A SIMPSON

Date of completion of Search
17 OCTOBER 1995

Documents considered relevant following a search in respect of Claims :-
1 TO 15

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	US 5357932	(FORD)	
A	US 5279272	(VOLKSWAGON AG)	
A	US 5078109	(FUJI)	

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